Guiding Sustainable Development in the Forest Bioeconomy: Environmental Life Cycle Assessments

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MiFBI Kraft Lignin Innovation Forum

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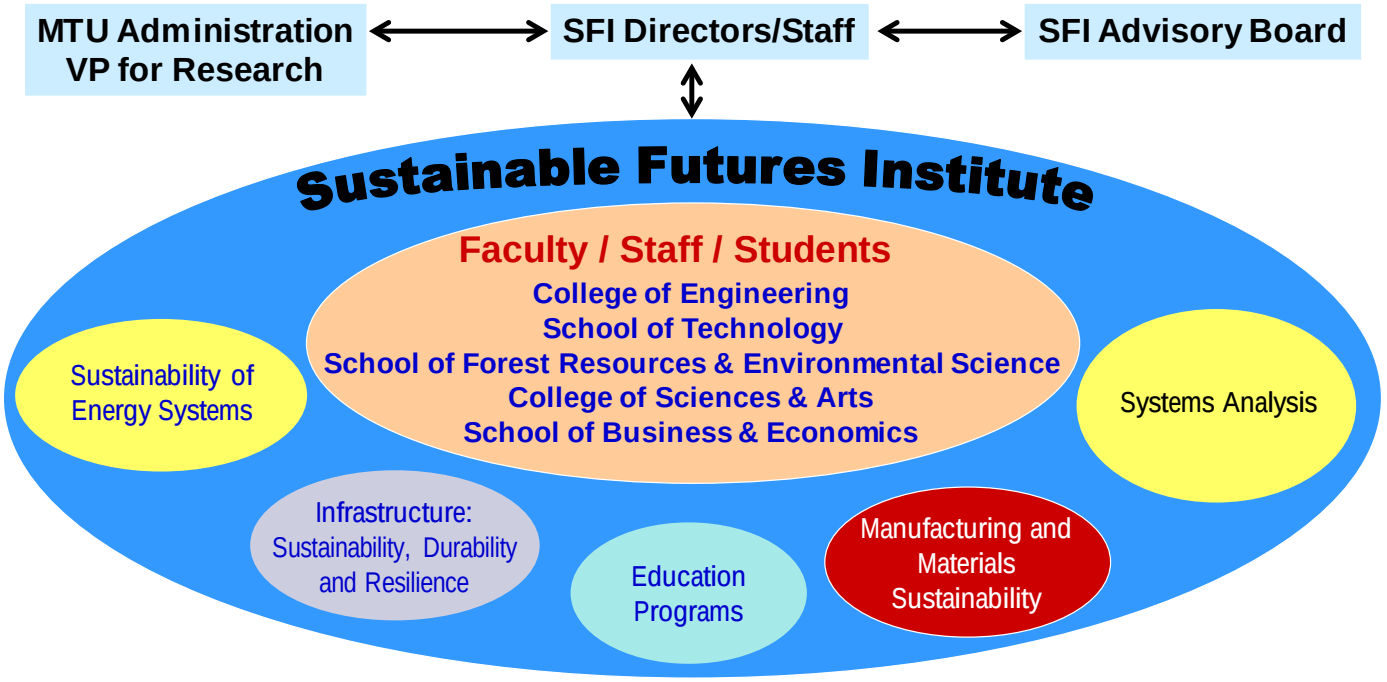
Presentation Outline

- Introduction: Sustainable Futures Institute
- Life cycle assessment (LCA) introduction
- LCA partners
- LCA case study: GHG emission results
- Future LCA for lignin-derived products
- Chemical Recycling of plastic or lignin residues
- Conclusions / Questions

SFI Organization



MISSION: enhance knowledge, develop technologies, and expand capabilities in working towards a sustainable future.

GOAL: to facilitate multi-disciplinary research and education sustainability projects with collaboration between academia-industry-government.

Life Cycle Assessment (LCA)

LCA is a Comprehensive Methodology

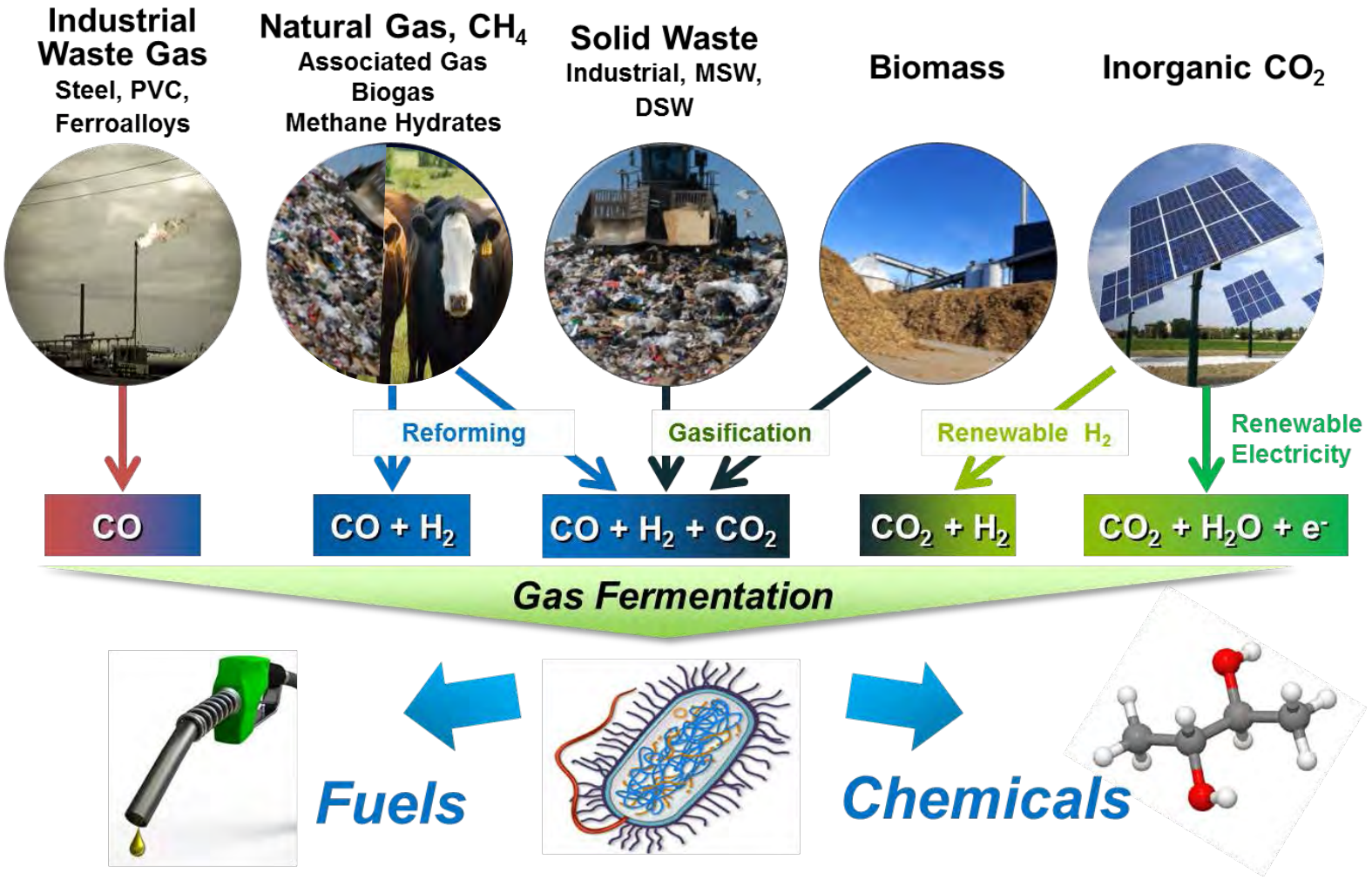
- Products and Processes:
  - Environmental profile is multi-category
- Life Cycle Approach
  - “Cradle-to-Grave” system boundary
  - Recycle-Reuse: “Cradle-to-Cradle”
- ISO 1404x Standards
  - Goal Scope through Interpretation of Results

LCA Partners

Most of our LCA work has focused on advanced biofuels, bioenergy, and crop systems.

Background – LanzaTech Process

Waste Carbon as a Resource



Results – Displacement Allocation

	GHG Emissions (**g CO_{2eq} / MJ EtOH**)			
Item	BOF	Corn Stover	Forest Residue	Switchgrass
C Sequestration + Vents [a]	-79	-80.2	-80.2	-80.2
Feedstock Procurement	0	11.2	6.6	14.9
EtOH Production [b]	1.8	1.3	1.3	1.3
Utilities (heat and power) [c]	28.8	-6.3	-6.3	-8.1
Anaerobic Digestor Emissions	6.8	7.5	7.5	7.5
Waste Treatment [d]	0.9	1.1	1.0	1.1
EtOH Transport	0.7	0.7	0.7	0.7
EtOH combustion	71.4	71.4	71.4	71.4
Total GHG Emissions	**31.4**	**8.0**	**1.5**	**11.7**
Percent Reduction (%) (petroleum jet)	**67%**	**92%**	**98%**	**88%**
	Petroleum Gasoline 86.4 g CO_{2eq} / MJ (GREET 2014)			

a Refers to fermentation vent; *b* Refers to nutrients, water, chemicals, etc.; *c* Refers to net emissions from energy imports plus emission from combustion of AD biogas; *d* Includes wastewater treatment and solid waste disposal

LCA of LignoForce Lignin?

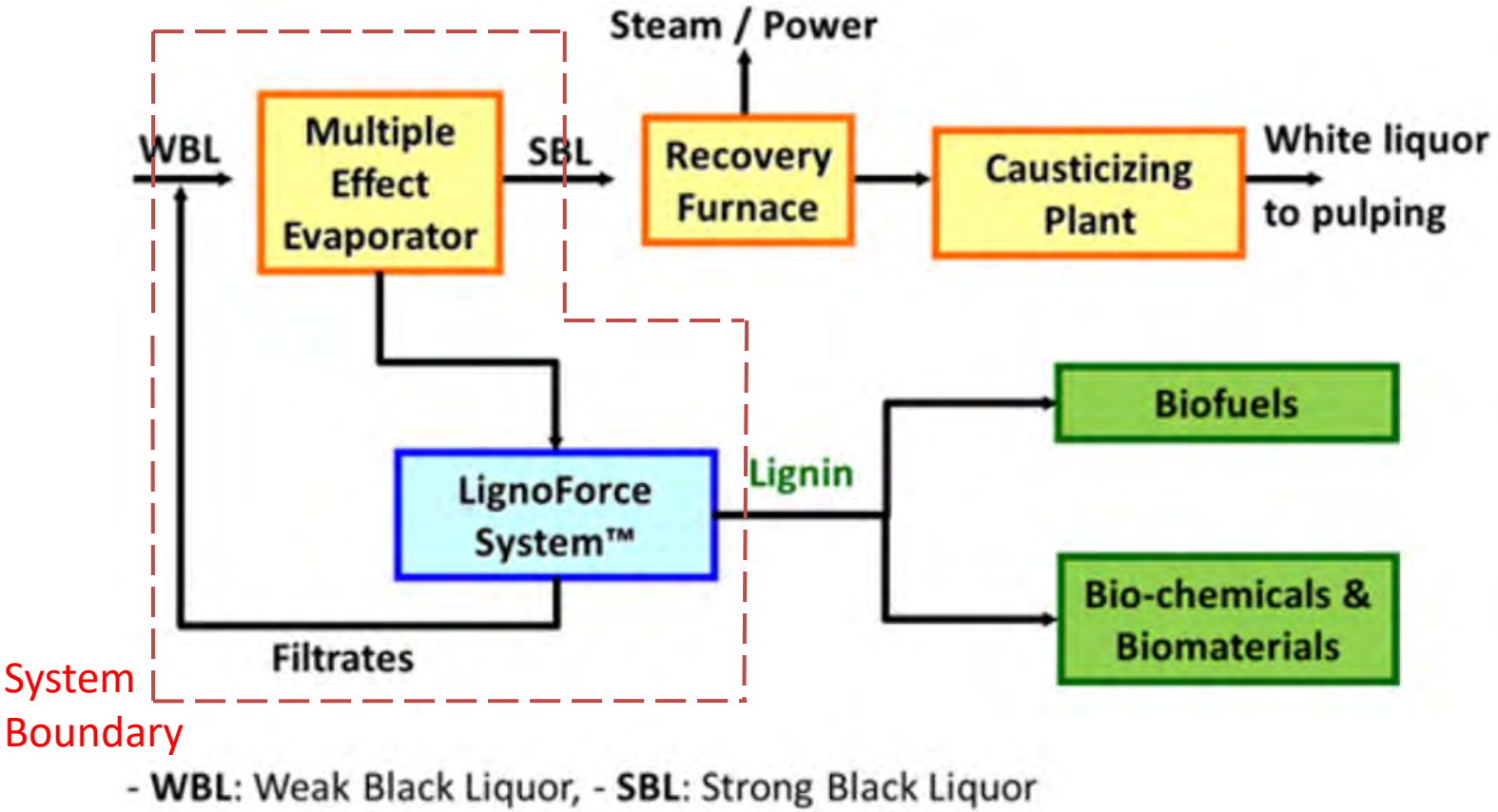


Image from Kouisni et al. 2016, *Sustainable Chemistry and Engineering*, 4, 5152−5159

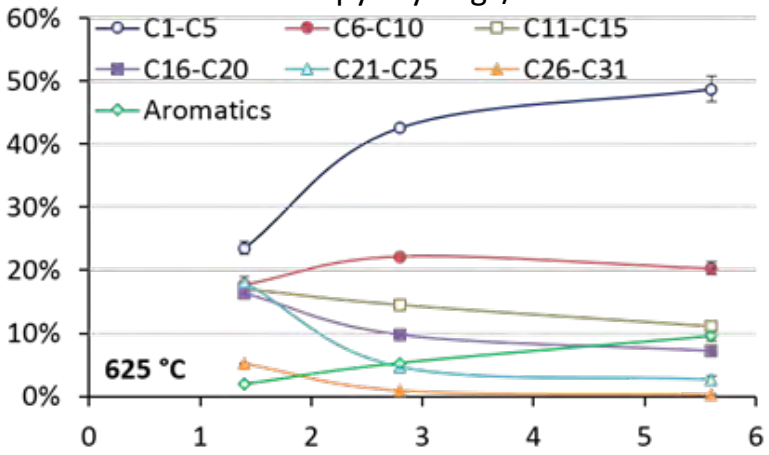
Chemical Recycling of Plastics

Current Project-Polyethylene Waste Remanufacturing

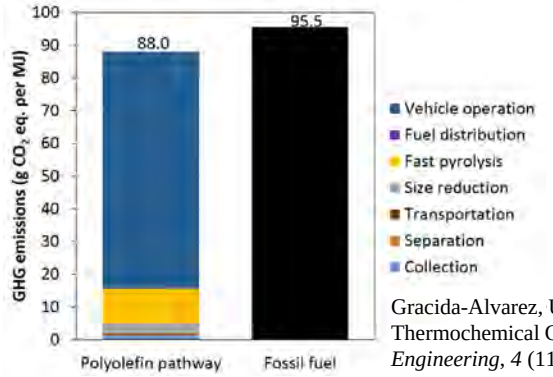
Fast Pyrolysis:

> 600°C, no O_2

Micropyrolysis gc/ms



Residence Time of Vapor (s)



Hydrocarbon Products

C1-C4 gases, Gasoline range liquids
Diesel range liquids, Lubricants - liquids
Waxes –solid, Aromatics - liquids

Ulises Gracida-Alvarez
Ph.D. Candidate

Gracida-Alvarez, U.R.,et al.., (2016) Resource and Greenhouse Gas Assessments of the Thermochemical Conversion of Municipal Solid Waste in Mexico, *ACS Sustainable Chemistry & Engineering*, *4* (11), pp 5972–5978 DOI: 10.1021/acssuschemeng.6b01143

We have developed a novel two-stage micropyrolysis reactor with fine control over temperature, heating rate, and vapor residence time. This reactor could process lignin to find optimum conditions for production of lignin-derived high value products

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